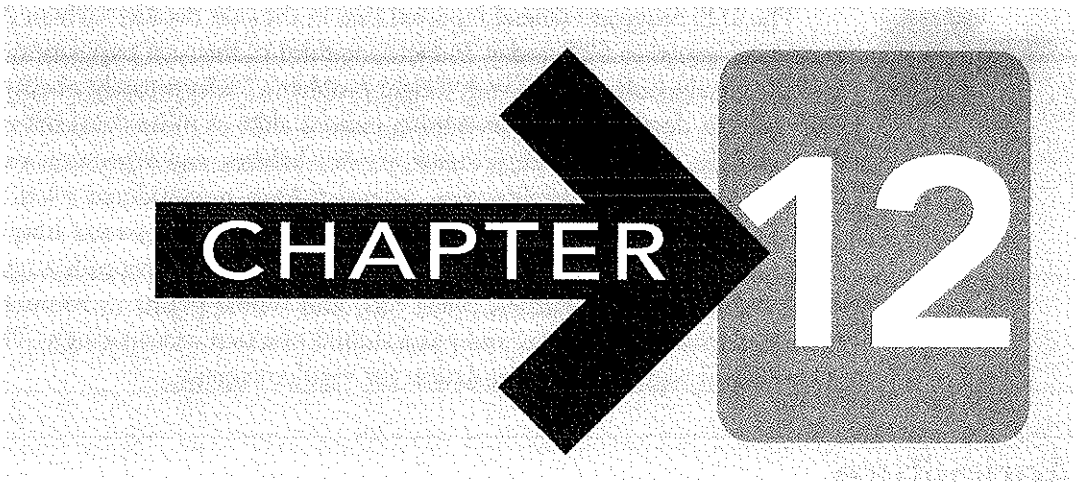


Agriculture and Aquaculture

IN THIS CHAPTER

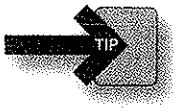
Summary: Cultivatable land is shrinking as more and more is used for housing, businesses, and other societal needs. Developed and developing countries must feed growing populations in sustainable ways by using modern methods to produce high yields of nutrient-rich and high-protein food.

Keywords

- Malnourishment, aquaculture, bycatch, target species, monoculture, polyculture, nonnative species, green revolution, genetic engineering, pesticide, biocide

Human Nutrition

Human beings have specific nutritional requirements needed to grow and thrive. These include proteins, vitamins, and minerals. A person can get enough caloric energy from food, but if the right nutrients aren't present in the food, the person becomes malnourished. *Malnourishment* is a nutritional imbalance caused by the lack of important dietary elements or the inability to absorb essential nutrients from food. The United Nations' Food and Agriculture Organization (FAO) estimates nearly three billion people suffer from protein, vitamin, and mineral deficiencies.



The most common nutritional problems are *anemia* (low iron in the blood), *goiter* (too little iodine for mental development, metabolism, and thyroid function), and *vitamin A deficiency* (causes blindness). Folic acid deficiencies cause problems in fetal brain development including *anencephaly* (no brain). Sufficient protein intake is also important in development.

However, many people in developed countries eat too much protein, salt, sugar, and fat, but not enough fiber. The result is unhealthy weight gain and *obesity*, defined as more than 30 pounds over ideal weight for a person's height and age.

The U.S. Surgeon General reported that in the past decade, 40% of Americans were overweight compared to 62% today. In fact, one-third of the total population is obese. The United States is not the only country with weight problems. Unfortunately, obesity is stretching around the world to developed and developing nations alike as more countries mimic Western diets. With this rise, the rates of heart attack, stroke, diabetes, and depression are also increasing.

To combat this unhealthy rise, scientists have reconsidered what makes up a healthy diet. The four basic food groups of meat, dairy, fats, and sweets have been sidelined to a much smaller percentage of the daily diet. Modern food pyramids advise larger portions of nuts, beans, fruit, vegetables, plant oils, and whole grains as foundational components. Processed bread, cereal, rice, and pasta should be eaten very sparingly. This recommendation is combined with a recommendation for regular exercise.

Agriculture

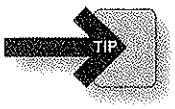
Types of Agriculture

The three main grain crops eaten by humans are wheat, rice, and maize (called corn in the United States). Combined, 1,900 million metric tons are grown annually across the globe. In fact, wheat and rice make up 60% of the calories consumed by humans.

Potatoes, barley, rye, and oats, grown at higher altitudes are important in northern Europe and Asia. Roots and tubers, grown in equatorial climates, feed people in the Amazon, Africa, and the South Pacific.

Fruits and vegetables are important because they contribute high levels of vitamins, fiber, carbohydrates, and minerals needed for development and overall health.

Although thousands of plant species have been grown for food over time, only 16 species are currently cultivated. Which plants are grown in an area is determined by climate, pests, soil, and other factors. These plant species include winged beans, which grow well in hot humid climates, and tricale, a hybrid of wheat and rye that flourishes in sandy, infertile soil.



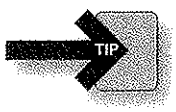
The huge increases in yield obtained through modern cultivation techniques has become known as the *green revolution*. These increases have allowed food crop production to keep pace with worldwide gains in human population.

Genetic Engineering and Crop Production

A hundred years ago, crops were pollinated by wind and insects. The average wheat yield was around 25 bushels per acre. Today it is a different story. By selectively transferring genetic material to make plants stronger, more drought tolerant, and resistant to insects, modern wheat yields average between 130 and 250 bushels per acre. Plant hybrids such as dwarf high-yielding wheat and rice raise production by 3 to 4 times the normal rate.

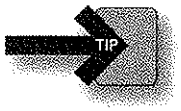
Genetic engineering is the bioprocess of taking DNA (blueprint proteins) from one species and splicing it into the genetic material of another.

Genetic cultivation methods greatly increase the quality and amount of food produced on the land. When DNA is combined in ways to augment certain characteristics in a species' natural growth, the result is known as a *genetically modified organism* (GMO).



The good thing about GMOs is that they can be created to thrive in environments with frost, low rainfall, high salt, and low nutrients, and even disease resistant. Some plants are designed to produce their own natural pesticides and eliminate the need for toxic chemicals. Some allergens can even be removed from plant strains.

One criticism about genetic engineering is that new strains of superweeds, toxic plant by-products, or other harmful consequences of human tinkering with nature will upset natural ecosystems. If GMOs cross with wild species or produce unwanted resistance to pesticides, later generations may pay the price. One way to limit this problem is to plant some field sections with non-GMO strains to keep insects from developing resistance to antipest strains.



Currently, about 82% of soybeans, 71% of cotton, and 25% of all corn in the United States are GMOs. In fact, it has been estimated that over 60% of all processed food in America has GMO ingredients.

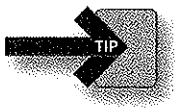
Irrigation

Another agricultural method that has come under scrutiny is water use and distribution. Many farmers use flood, ditch, or sprinkler irrigations, which allow for massive evaporation from the land and crops. More is lost through runoff.

In countries with few water resources, conservation is crucial. Watering plants directly without water logging the soil is important. One method uses *drip irrigation* to provide water directly to thirsty plant roots.

The additional cost of maintaining pumps, canals, dams, and reservoirs is another reason for water conservation and better irrigation methods. In some regions, farmers have overpumped underground reservoirs and lowered the water table to below accessible levels. Now they want government funds for canals and other infrastructure to divert river water for their crops. Opponents point out the impacts of river diversion on fishing, hunting, and other commercial and recreational water use. Since pumping irrigation water is common, these kind of decisions have broad application to worldwide agriculture.

Pest Control



A *biological pest* lowers the quantity, quality, or value of resources. Most people equate pests with insects, since mosquitoes, cockroaches, gnats, and locusts affect humans and crops negatively. In fact, insects make up roughly 75% of all species on Earth. Most insects, however, are harmless to humans. Out of the roughly 1 million species of insects described so far, no more than 1,000 are considered serious pests.

Types of Pesticides

Historically, humans have controlled pests with smoke, salt, sand, and insect-repelling plants. The ancient Sumerians used sulfur to control insects and mites 5,000 years ago. Greeks and Romans used oils, ash, lime, and other compounds to protect themselves, their crops, and their animals from pests.

Modern pest control is performed by eliminating pests' living conditions, such as swamps. *Pesticides* are chemicals that kill or repel certain pests, while *biocides* kill a broader range of organisms. In addition to their use for pest control, biocides are also found in adhesives, paints, leathers, petroleum products, and plastics, as well as recreational and industrial water treatment in totals of around 300 million pounds per year. This large amount accounts for less than 10% of the total U.S. yearly pesticide use.

Around 80% of all pesticides in the United States are used in agriculture or food storage and shipping. Chemicals, which kill specific targets, are named accordingly. These are *insecticides* (kill insects), *herbicides* (kill plants and weeds), *acaricides* (kill spider mites and ticks), *rodenticides* (kill rats and mice), and *fungicides* (kill molds and fungus). Pesticides are also described by application methods such as fumigation (gassing) to treat wood against insects. Pesticides are categorized by chemical structure. These are inorganic, natural organic,

Table 12.1 Pesticides use many different chemicals to eliminate a variety of pests.

PESTICIDE TYPE	CHEMICALS
Inorganic	Mercury, arsenic
Natural organic	Nicotine, rotenone, turpentine, phenols, aromatic oils
Fumigants	Carbon tetrachloride, carbon disulfide, ethylene dichloride, methylene bromide
Chlorinated hydrocarbons	DDT, chlordane, aldrin, dieldrin, toxaphene, lindane, paradichlorobenzene (mothballs)
Organophosphates	Parathion, malathion, dichlorvos, chlorpyrifos, dimethyldichlorovinylphosphate (DDVP)
Carbamates	Urethane, carbaryl (Sevin), aldicarb (Temik), carbofuran (Baygon), Mirex
Microbial/biological agents	Bacteria (*Bacillus thuringiensis*), ladybugs, lacewings, wasps

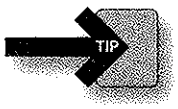
fumigant, chlorinated hydrocarbons, organophosphates, carbamates, and biological agents. Table 12.1 shows the makeup of these various pesticides.

Costs and Benefits of Pesticide Use

Early environmentalists warned of random pesticide use as early as the 1950s, but it was not until the 1962 publication of the book, *Silent Spring,* by marine biologist Rachel Carson that environmental contamination came into broader public view. She pointed out the hazards of careless application and spraying of herbicides and pesticides.

One such pesticide hazard became apparent with DDT's (dichlorodiphenyltrichloroethane) impact on predatory nontarget bird species 50 years ago. Known as an excellent broad-spectrum insecticide, DDT built up (*bioaccumulation*) in the tissues of lower organisms like zooplankton (0.04 ppm) until it was stored in toxic levels (25 ppm) in the tissues of predatory birds (falcons and eagles) eating poisoned rodents and other small animals. This buildup in the highest members of a food chain is known as *biomagnification.*

Pesticides often poison nontarget species. Pesticide use has been directly linked to mass killings of migrating birds (robins in 1972), and the decline of migrating Atlantic salmon in Canada due to 4-nonylphenol, a strong hormone disrupter.



Pesticide resistance is also a problem since every target species has genetically diverse individuals resistant to pesticides. Since these resistant members of the targeted population then reproduce resistant generations, the population eventually resurges or rebounds from the pesticide hit. Farmers must use increasingly more pesticide to get the same crop protection. The pesticide use becomes an upwardly spiraling pesticide treadmill with farms hesitant to get off due to income loss from pest damage. At least 1,000 insect species and 550 weed and plant pathogens globally have developed chemical resistance.

Because of their stability, high solubility, and high toxicity, pesticides often have a big environmental impact. They accumulate in water and soil for years, and their effects are long lasting. Pesticides also evaporate from contaminated areas and then rain down on far distant areas.

Pesticides are often stored in the fat of animals. Dangerously high levels become concentrated and can cause birth defects and death in predators and prey alike. Species such as

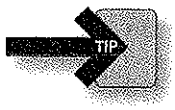
polar bears, porpoises, trout, eagles, whales, and humans at the top of the food chain suffer the most.

Pesticide Management

Since insects are increasingly more resistant to a single strategy, scientists and ecologists have come up with *integrated pest management.* This includes flexible and different application methods to kill insects and weeds. For example, hormones, which stop larvae growth, combined with mechanical vacuuming of adult bugs from plants has been successful. Breeding hybrid plants that are resistant to insects also lowers pesticide use. Careful monitoring of economic thresholds between pest damage and pesticide cost and application time is catching on as well.

Trap crops, small plots planted before the rest of the field, are sprayed heavily with pesticides trapping and killing insects that would harm the main crop. The trap crop is destroyed to protect farm workers and consumers from the concentrated pesticide. The rest of the field then grows relatively pest and pesticide free.

Relevant Laws



In the United States, three agencies are responsible for regulating pesticides used on food crops: the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the Department of Agriculture (USDA). The EPA controls the sale and use of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act, which calls for the registration (licensing) of all pesticide products. The EPA studies risks to humans and the environment from pesticides. Under the Federal Food, Drug, and Cosmetic Act, the EPA sets acceptable pesticide level limits in foods sold in the United States regardless of where it was grown. The FDA and USDA enforce use and allowable levels regulated by the EPA and have the authority to destroy any shipments found to be in violation of EPA limits.

In 1996, Congress passed the Food Quality Protection Act. This allows the EPA to set limits on combined pesticide exposures. This act determined that by 2006 the EPA had to reassess allowable pesticide levels on food and include a safety factor of 10 where complete information was not available on pesticide levels affecting children.

This Act also led the EPA to examine *inert* pesticide ingredients for the first time. These compounds, usually not listed on a label, are used to dilute or transport active chemicals. Of the 2,500 substances used for this purpose, over 650 have been identified as hazardous by local, state, and federal agencies. Over 50% have been identified as carcinogens, occupational hazards, and air and water pollutants. One example, naphthalene, is listed as a hazardous pollutant under both the Clean Air and Clean Water Acts.

Sustainable Agriculture

No one wants to use chemicals that cause cancer or birth defects, or harm nature. However, countries all over the world must feed their growing populations and produce income-generating crops. The trick is to do it in a sustainable way. When farmers grow nutritious crops while stopping harmful past practices, it is called *sustainable agriculture, regenerative farming,* or *agroecology.* Science advancements as well as past mechanical practices may be the answer.

Soil conservation and care is the best place to start by limiting erosion. In Asia, rice cultivation is carefully nurtured with organic material, keeping it healthy year after year. Topography methods such as contour plowing are replacing traditional planting techniques and substantially reducing water runoff and erosion. Mulch and ground cover species are also beneficial to the bottom line. Organic farms allow animals such as cows, chickens, and pigs to roam and eat native grasses and seeds. This produces healthier animals and a source of odorless organic fertilizer. Veterinarian and feed costs on these farms, along with the reduced need for workers, are down.

Marine Resources

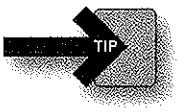
The importance of marine resources to humans is obvious. Fish and shellfish give us a valuable source of food protein and livelihood for many in the seafood industry. Other marine resources meet the needs of the general population and provide jobs. The question is, "To what extent can the oceans continue to meet human needs?"

Overfishing

Fisheries in many countries remain unregulated and inadequately studied. Even where research has been done, political and economic pressures override scientists' recommendations. In fact, most fisheries, close to coasts impacted by human activities, have been overfished. This is a major problem with ocean fisheries worldwide.

Since over 15% of all animal protein for humans comes from seafood, the fishing industry always has a market for its catch. To meet this demand, technology has been used to increase yield. Unfortunately, too many boats using efficient technology have impacted three-quarters of the world's edible ocean fish, crustaceans, and mollusks according to United Nations' estimates. Conservation must be observed by all seafaring countries to have any hope of sustaining declining fish populations.

Bycatch



When nontarget fish species or other marine animals are caught in nets or through other fishing methods, they are called *bycatch.* Accidental catching and killing of nontarget species, like nonmarketable "trash" fish and marine mammals (dolphins, sharks, etc.), have also impacted ocean ecosystems. The Food and Agriculture Organization (FAO) of the United Nations estimates for 1988–1990 indicate an average of 27 million metric tons of fish per year were discarded as bycatch by commercial fishermen. This amount is roughly equal to one-third of the total yearly global catch. This does not include the unintended killing of several hundred thousand sea turtles and marine mammals each year. Fishing methods such as *bottom trawling, gill netting,* and *longlining* are especially subject to bycatch. Shrimp trawlers catch and throw away an estimated 9 pounds of nontarget species for every 1 pound of shrimp caught.

As the public finds out about these problems, funding becomes available for research and development of new technologies. For example, when it was learned that thousands of dolphins were caught in tuna nets and drowned before they could be released, new escapable nets were designed. Public demand for "safer" tuna grew, and those companies refusing to change saw sinking sales.

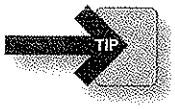
Nonnative (Alien) Species

When plants and animals found in one part of the world, with its own natural predators, diseases, and ecosystem controls, are transported to a far distant location, they are known as *nonnative* or *alien* species. In their new location, they increase, die, or something in between.

Plants and animals transplanted geographically to a formerly unknown area are known as *nonnative (alien) species.*

Many times, a new species can't live in a new environment and fails to prosper. Other times, however, the new species grows, crowds out native species, and destroys the local ecosystem.

In the ocean, alien species are introduced through a ship's ballast water. When ships fill their ballast tanks to adjust their stability in the water, they suck in the local marine inhabitants. Later after emptying the ballast water elsewhere, stowaway passengers are expelled. Scientists think as many as 3,000 alien species are transported around the world in ships daily.



Nonnative species affect coastal waters more than the open ocean. In coastal zones, where transplanted species are often biologically and ecologically distinct, alien species have a greater impact. Species transported from tropical regions of the Atlantic to the Pacific are frequently even more disruptive because there is little natural exchange between these oceans. Transplants between the Indian Ocean and the Atlantic Ocean are not all that different and do not have as serious effects since these oceans are connected.

Because of worldwide shipping, however, the impact of alien species has increased dramatically. Global population growth has forced many nations to bring in food and other products from trade partners. Many countries, formerly self-reliant, now depend on imported goods.

This shipping increase has caused a huge increase in the introduction of marine alien species into new ecosystems incapable of coping with them. For example, in San Francisco Bay, California, the ecosystem has been overwhelmed by many new alien species. Currently there are over 200 different alien species living in San Francisco Bay, severely impacting native species and the overall ecosystem. Although alien species have not completely wiped out native species, the Bay's natural processes have changed a lot.

Besides changing native marine ecosystems, alien species can also affect humans. Zebra mussels, an introduced species in the Great Lakes, have done everything from disturb native species to clogging pipes. However, on the plus side, they increased toxin filtration from the water.

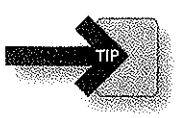
Aquaculture

Growing marine or aquatic species in net pens or tanks is known as *aquaculture.* Today, nearly 25% of the world's seafood comes from fish farms or aquaculture. Fish are raised in ponds that take relatively little land and may not be rich enough to grow other food crops.

However, aquaculture is not without problems. Raising high-value carnivorous species such as salmon and sea bass can reduce the number of wild species, since they are often used to start stock populations. Worldwide, thousands of hectares of mangrove forests and wetlands are destroyed to build fish ponds. These natural environments are essential as nurseries for many different marine species.

Additional problems arise from aquaculture pens anchored near shore where disease, escape of exotic species, and pollution from feces, excess food, and antibiotics endanger native species. This is not a problem with small family operations, but countries with huge aquaculture pens greatly intensify these environmental problems.

Mixed Species



Raising different fish species together (*polyculture*), such as the grass carp (eats plants) and silver carp (filter feeder of small organisms), reduces many aquaculture problems caused by raising only one species (*monoculture*). The fish farm species are healthier and do not deplete the same food supply. Because of these benefits, polyculture farming yields are often 50% higher per hectare than monoculture aquaculture farming.

› Review Questions

Multiple-Choice Questions

1. Zebra mussels are

   (A) the largest of the mussels
   (B) actually more spotted than striped
   (C) an introduced alien species in the Great Lakes
   (D) related to zebra clams
   (E) a native species

2. Growing marine or aquatic species in net pens or tanks is known as

   (A) cross cultivation
   (B) a risk-free industry
   (C) bioculture
   (D) an easy source of iodine
   (E) aquaculture

3. Species transported from tropical regions of the Atlantic to the Pacific

   (A) have no impact on the new environment
   (B) have greater impact on the new environment
   (C) have limited impact on the new environment
   (D) are seldom transported to another environment
   (E) don't survive in a new environment

4. When DNA is combined in ways to augment certain characteristics in a species' natural growth, the result is known as a

   (A) nonnative species
   (B) relict species
   (C) transplanted organism
   (D) genetically modified organism
   (E) nonviable organism

5. When nontarget fish species or other marine animals are caught in nets or through other fishing methods, they are called

   (A) surplus species
   (B) bycatch
   (C) alternate species
   (D) trash fish
   (E) game fish

6. The huge increase in yields obtained through modern cultivation techniques has become known as the

   (A) GMOs
   (B) cross-pollination methods
   (C) aquaculture dilemma
   (D) genetic revolution
   (E) green revolution

7. Small land plots that are planted early, heavily sprayed with pesticides, and their crop later destroyed are known as

   (A) hectares
   (B) sustainable agriculture
   (C) trap plots
   (D) testers
   (E) polluted plots

8. Which of the following has caused the greatest increase in the introduction of marine alien species into new ecosystems?

   (A) Tourism
   (B) Air travel
   (C) Shipping
   (D) Commercial fishing
   (E) Home aquariums

9. Fishing methods like bottom trawling, gill netting, and longlining are especially subject to

   (A) crew safety policy
   (B) seasonal variation
   (C) high fuel costs
   (D) poor yields
   (E) bycatch

10. The Food Quality Protection Act caused the Environmental Protection Agency to

    (A) assess inert ingredients for the first time
    (B) raise levels for pesticides
    (C) determine whether carcinogens existed in food
    (D) protect the elderly from DDT
    (E) send hybrid rice to third-world countries

11. Agroecology is another word for

(A) tillage
(B) sustainable agriculture
(C) degenerative farming
(D) strip mining
(E) historical agriculture

12. Something that lowers the quantity, quality, or value of resources is known as a

(A) growth factor
(B) decimator
(C) biocide
(D) agricultural sink
(E) biological pest

13. When species are transported geographically to an unknown area, they are called

(A) native species
(B) game fish
(C) exotics
(D) nonnative species
(E) functional species

14. Three agencies are responsible for regulating pesticides used in food: the Environmental Protection Agency, the Food and Drug Administration, and the

(A) Centers for Disease Control
(B) Department of Health and Human Services
(C) Department of Agriculture
(D) National Institutes of Health
(E) Department of Homeland Defense

15. Rodenticides kill rats and mice, while ticks and spider mites are killed by

(A) aracnicides
(B) mitocides
(C) fungicides
(D) acaricides
(E) herbicides

16. It has been estimated that over 60% of all processed food in America contains

(A) GMO ingredients
(B) fatty acids
(C) carcinogens
(D) DDT
(E) phosphorus

17. Hormones that stop larval growth, combined with mechanical vacuuming of bugs from plants, are examples of

(A) crop rotation
(B) low input agriculture
(C) integrated pest management
(D) cross discipline activation
(E) plant desertification

18. DDT, which kills malaria-carrying mosquitoes, had a large negative impact on

(A) horses
(B) local ladybugs
(C) earthworms
(D) nontarget predatory bird species
(E) migrating robins

19. One method to conserve water and make sure it gets directly to plant roots is through

(A) sieve sleeve irrigation
(B) drip irrigation
(C) rolling sprinklers
(D) flood irrigation
(E) crop circle sprinklers

20. Organic farms have lower feed and veterinarian costs since their animals are

(A) smaller in size
(B) crowded into barns
(C) healthier
(D) raised in larger herds
(E) fed GMO ingredients